Newly formed dust within the circumstellar environment of SN Ia-CSM 2018evt

Lingzhi Wang et al. (Nature Astronomy)

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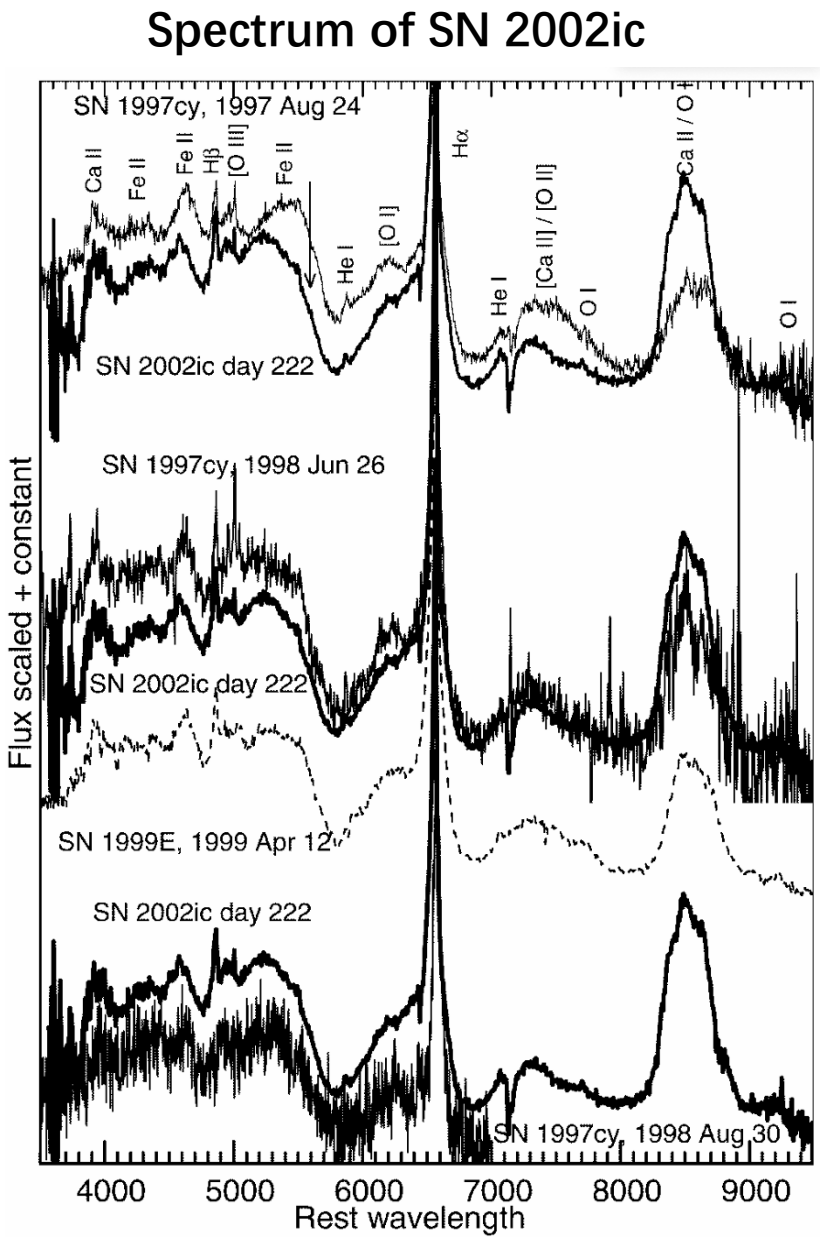
1. Introduction

Dust associated with various stellar sources in galaxies at all cosmic epochs remains a controversial topic.

To date, freshly formed dust has been observed in a handful of core-collapse (CC) supernovae, and the interaction zone between CSM and the ejecta.

A rare subclass of Ia supernovae is denoted SN Ia-CSM, which is thought to be an exploding WD surrounded by a substantial amount of CSM.

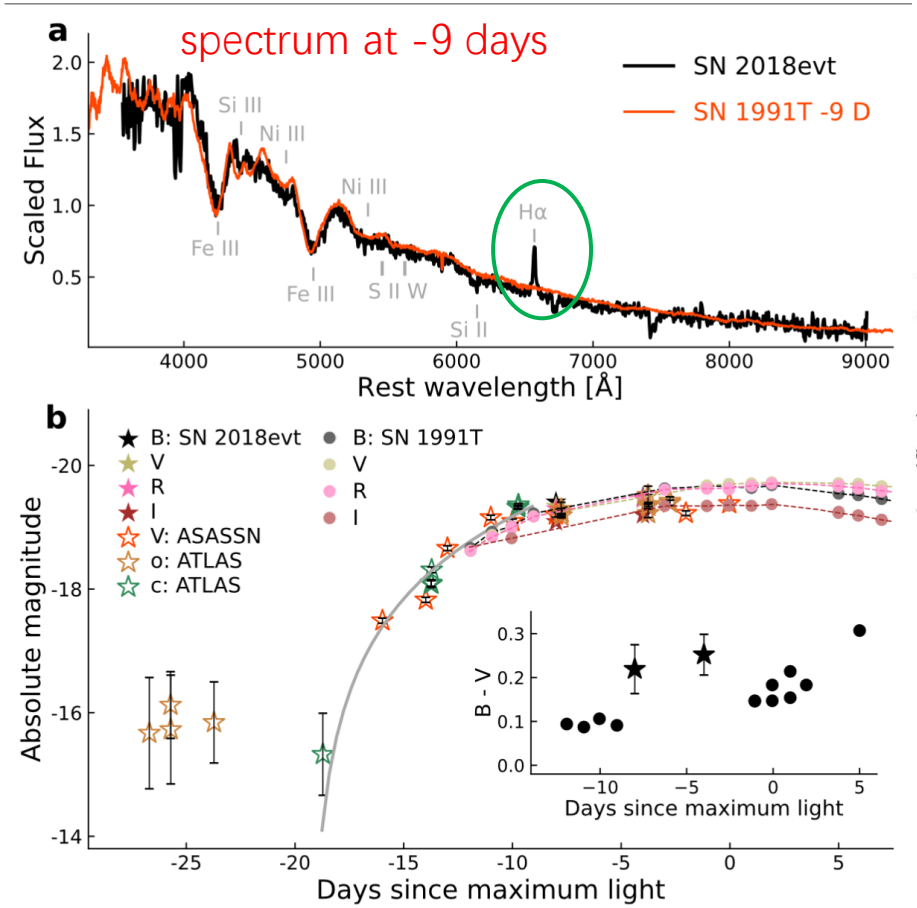
A number of additional Ia-CSM supernovae have been discovered and studied in detail in recent years.(e.g., SN 2005gj, PTF11kx, SN 2012ca, SN 2013dn, SN 2015cp)



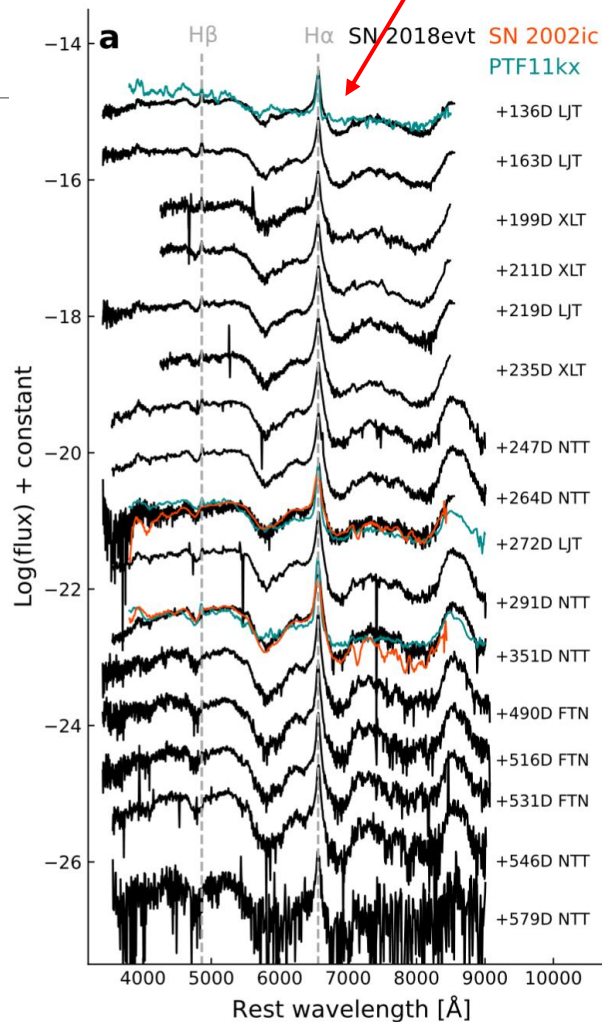
J. Deng+, 2004

2. Observational properties of SN 2018evt

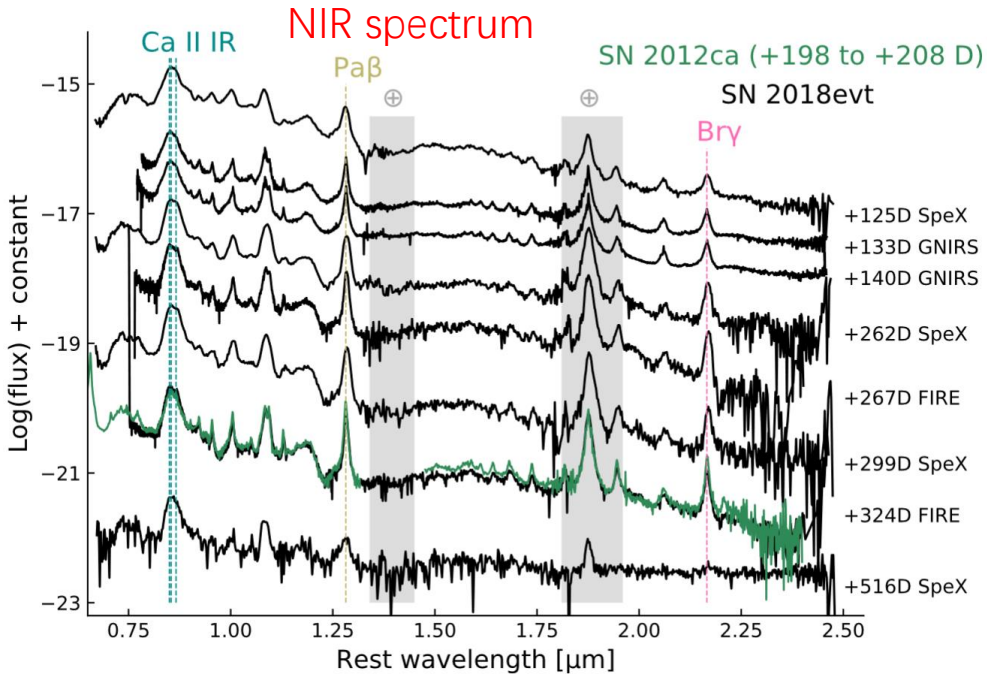
- SN 2018evt is a Ia-CSM SN
- Spiral galaxy MCG-01-35-011
- Redshift： 0.02523



The presence of the Hα line makes it a Ia-CSM SN similar to SN 2002ic.

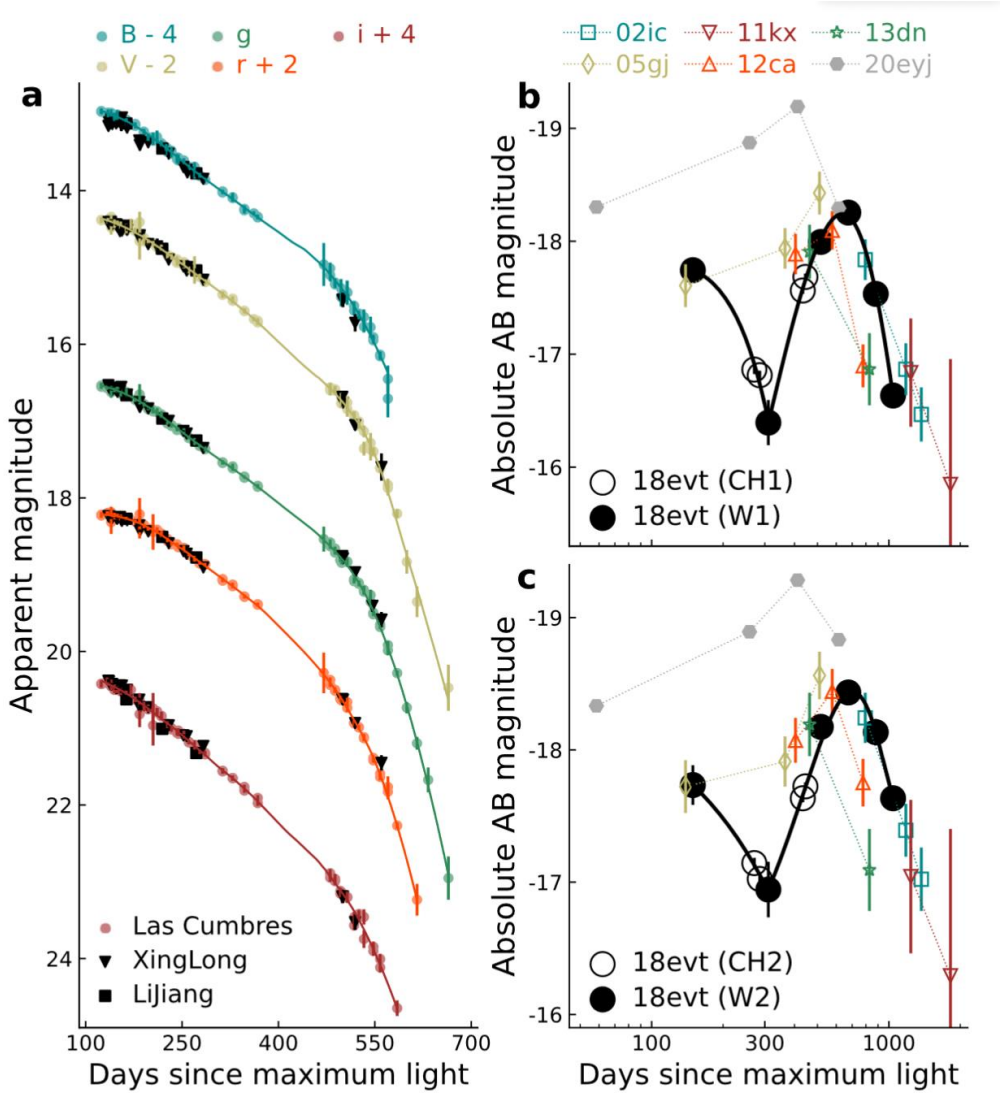


The entire spectral sequence of SN 2018evt directly resembles other well-observed Ia-CSM supernovae events such as PTF11kx and SN 2002ic.

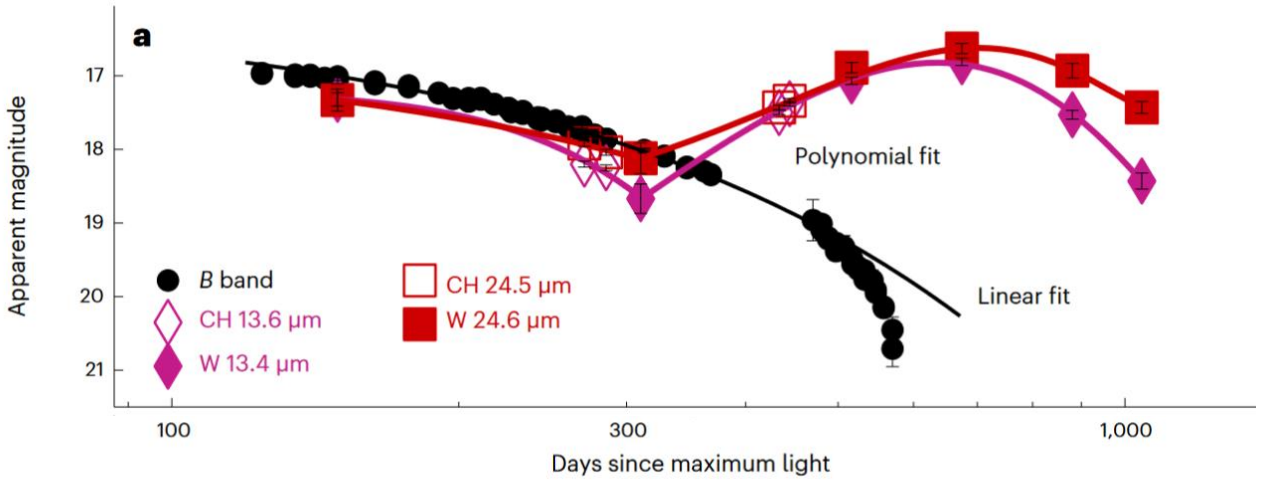


2. Observational properties of SN 2018evt

The optical and MIR light curves

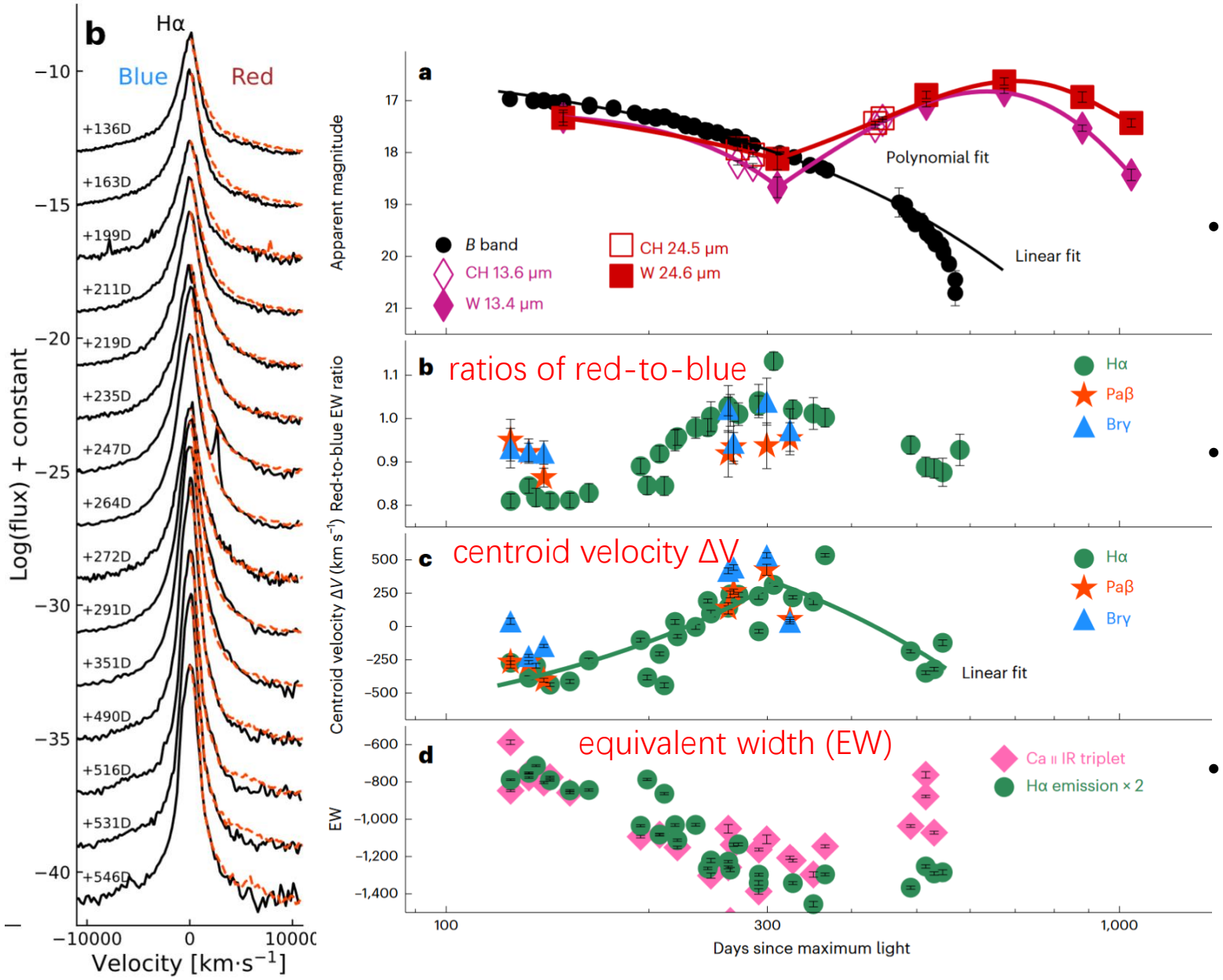


The typical long-duration optical/IR light curves at late time ,indicating a continuous interaction between the expanding ejecta and a radially extending CSM.



This behaviour is not only distinct from the steadily fading light curves in optical bandpasses but also has not been seen in any previous Ia-CSM supernovae in similar MIR filters.

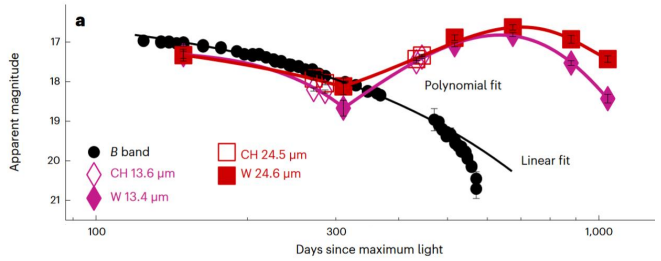
2. Observational properties of SN 2018evt

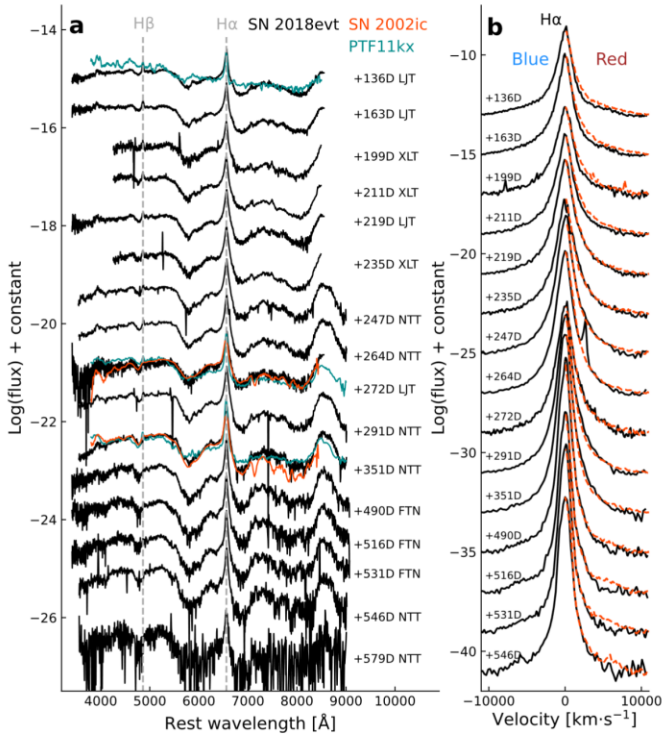


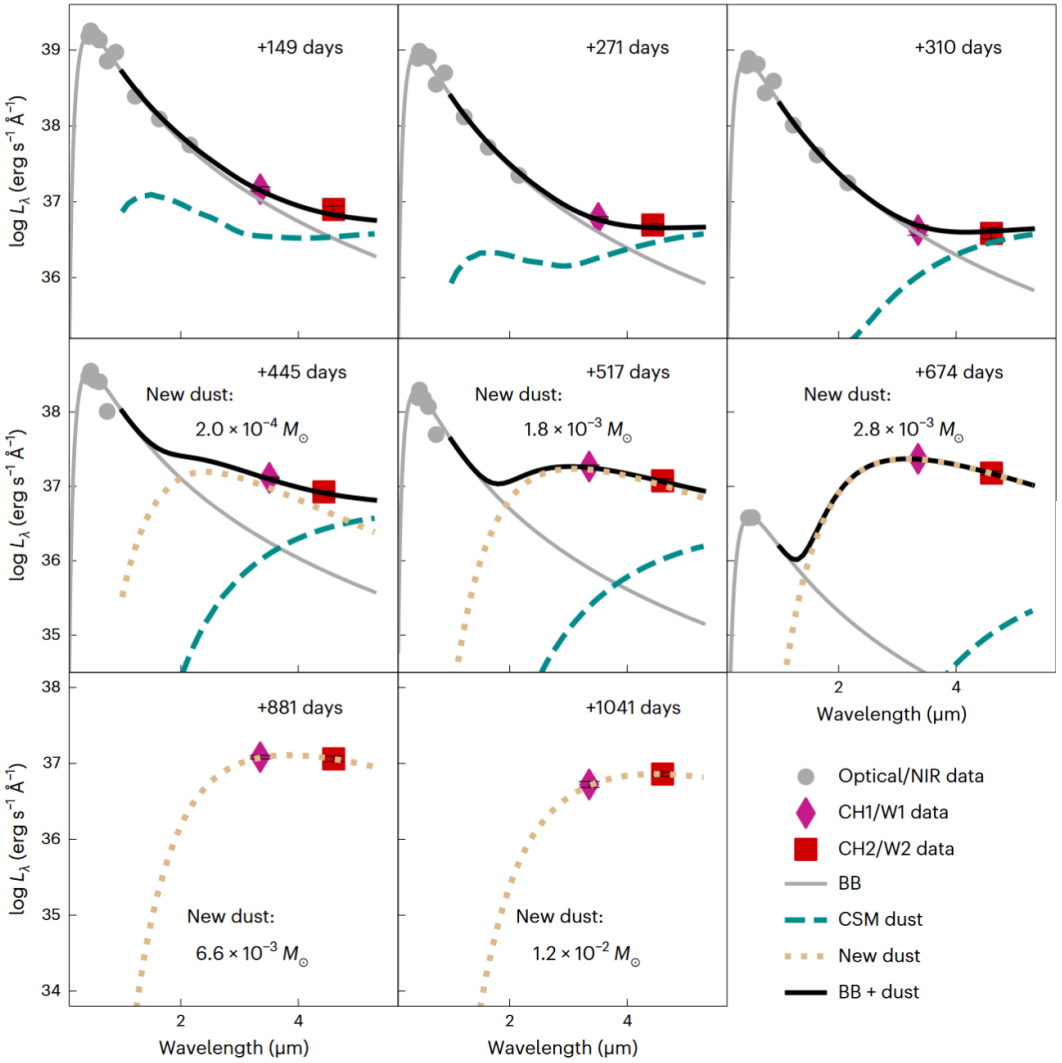
- The ratios of red-to-blue wing flux increase steadily from day +125 to ~+310 but turn over and decrease afterward, in pace with the MIR flux evolution.
- The flux-weighted centroid velocity ΔV of the Hα line evolves steadily from the blueshifted side (−400 km s−1) to the redshifted side (+300 km s−1) before day +310 and thereafter moves gradually back to the blue side (−200 km s−1).
- The evolution of the EW of the Ca II NIR triplet also exhibits a fall and rise, in concert with the evolution of the MIR flux and the Hα line profile.

3. Explanation

In this case, a cold, dense shell (CDS) develops during the ejecta–CSM interaction. In this region, the ejecta and CSM mix produce suitable conditions that allow the condensation of dust grains on short timescales.

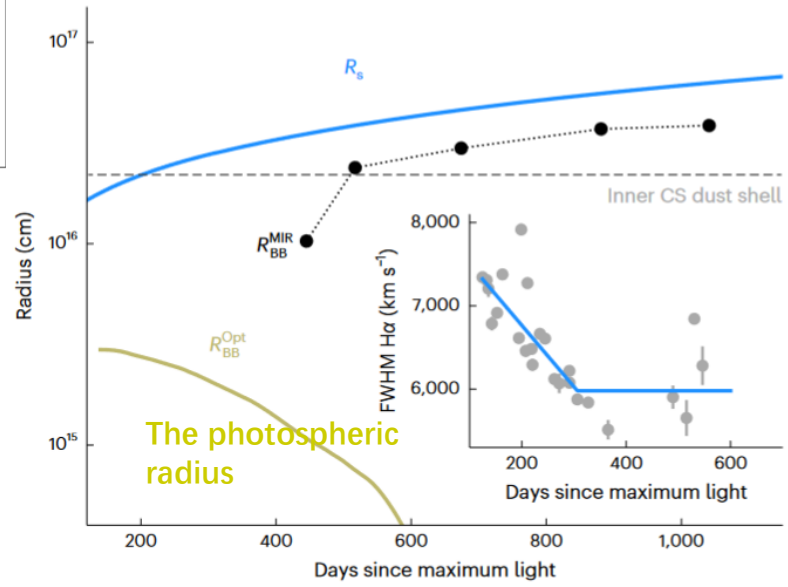






BB SED fitting : 6400–7000 K
MIR excess from dust : 100-1000K

R_{BB}^{Opt} decreases with time, indicating a progressive deviation of the BB photosphere from the expanding CDS, allowing the CDS to cool to a lower temperature.



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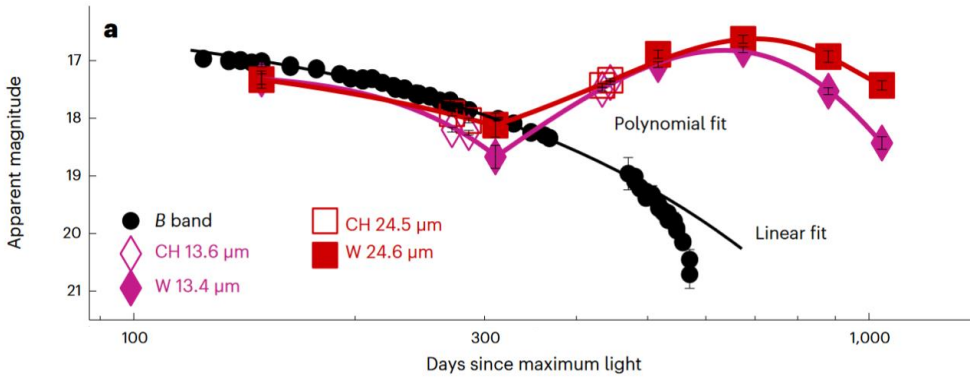
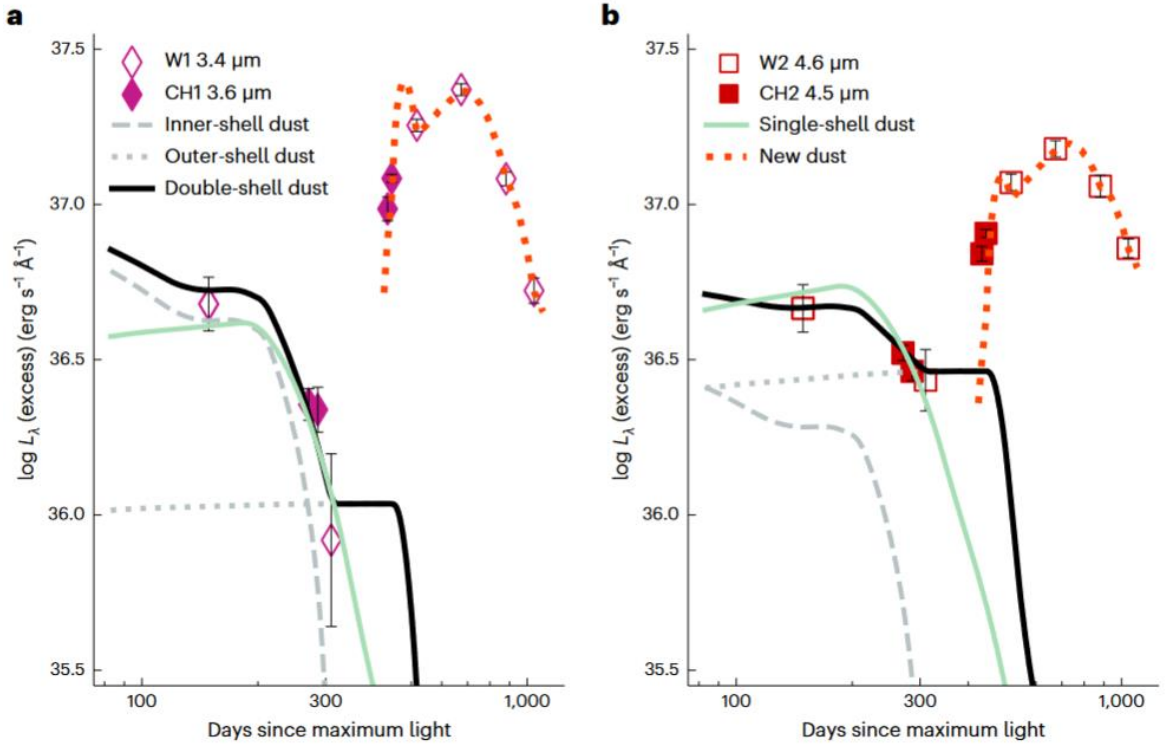


The subsequent brightening after day +310 would suggest that newly formed dust accounts for the later MIR emission, in either the postshock regions of the CSM or the cooling ejecta.

$\rho_{dust} \propto r^{-s}$, s=1.15

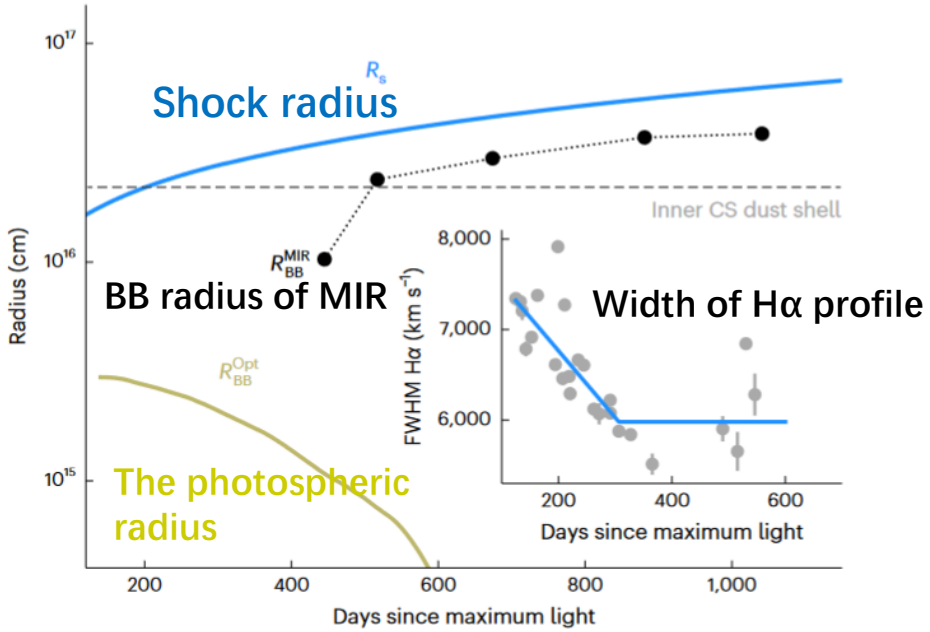


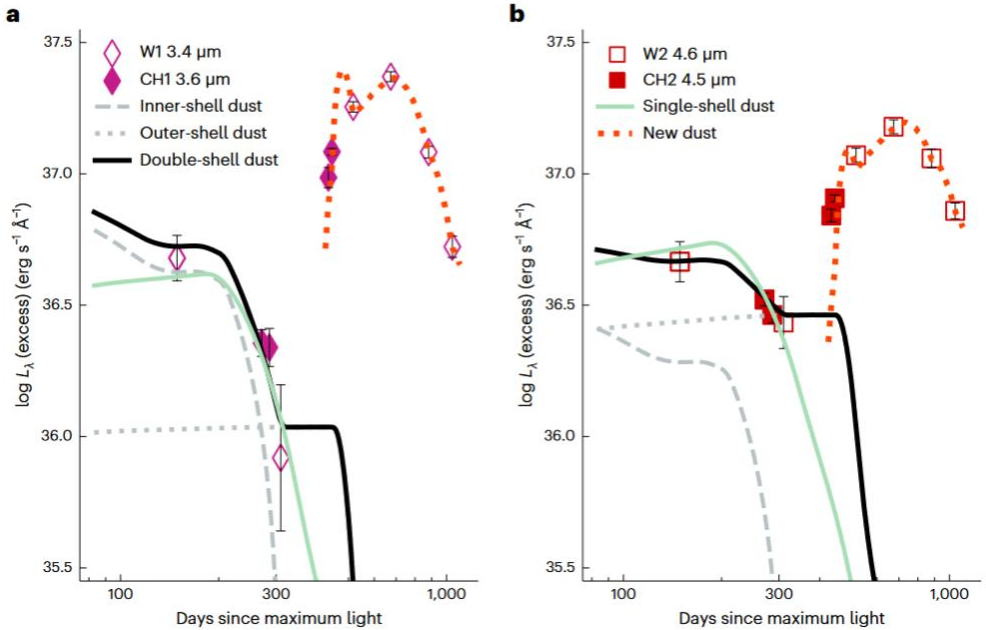
This shallower radial density profile implies enhanced dust content at larger distances from the progenitor star.

In the case of steady mass loss s=2, a reasonable fit also can be achieved by introducing two shells of pre-existing CSM dust before day +310, namely the double-shell model.

As the forward shock propagates outward, dust grain sublimation take place progressively within the inner shell, but the emitting dust grains in the outer shell remain unaffected early on.

3. Explanation

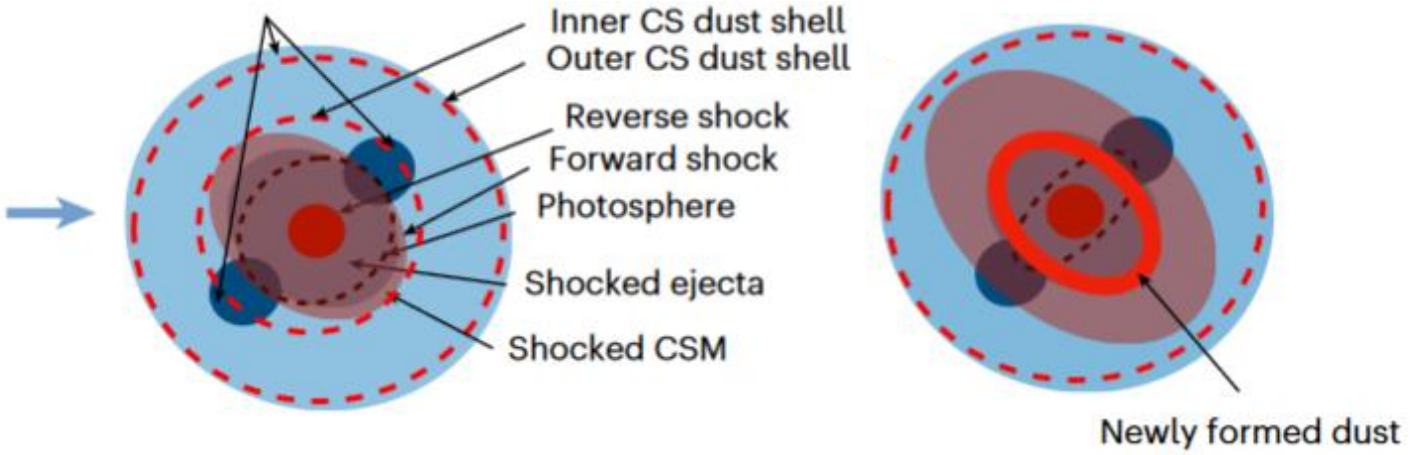




The BB radius R_{BB}^{MIR} of the newly formed dust content fitted to the SED after +310 days increases and remains within the shock radius Rs.

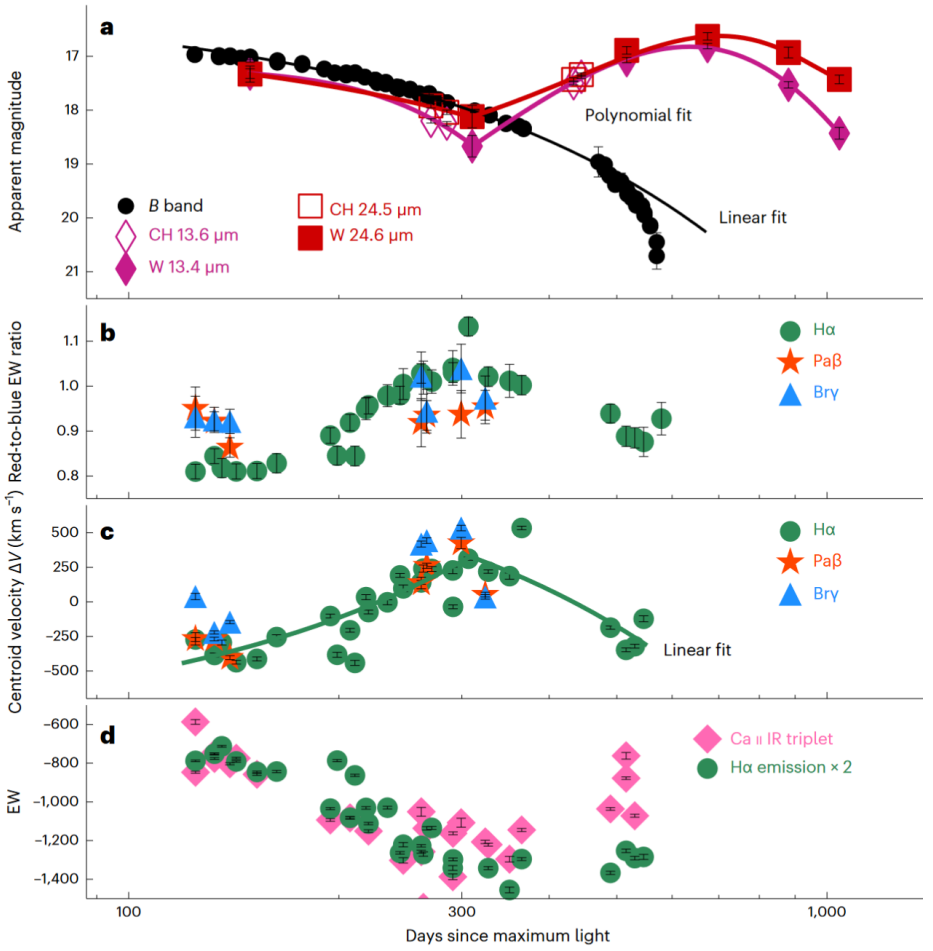
Dust survival close to the shock is possible if the dust distribution is patchy or in an opaque disk, in which the self-shielding of the dust particles is important.

The double-shell model assumes that a substantial amount of dust may survive the initial UV/optical emission of the SN explosion out to the inferred inner CS dust shell radius.



4. Summary

- Dust associated with various stellar sources in galaxies at all cosmic epochs remains a controversial topic.
- A rare subclass of Ia SN is denoted SN Ia-CSM, which is thought to be an exploding WD surrounded by a substantial amount of CSM.
- The spectra of SN 2018evt is similar to Ia-CSM SN 2002ic, but with an unexpected MIR emission excess at late time.
- The excess MIR emission requires notable additional emission source and can be well-attributed to the emergence of warm dust behind the forward shock.



Thanks.